PRODUCTION OF METHANE GAS BY ULTRASONIC MEMBRANE ANAEROBIC SYSTEM (UMAS) USING SEWAGE SLUDGE AS SUBSTRATE

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ABSTRACT

A study was conducted to verify the status of the application of Ultrasonic Membrane Anaerobic System (UMAS) in wastewater treatment, efficiency of UMAS in methane production and kinetic parameters in sewage sludge on methane production from sewage sludge by using UMAS. UMAS consist of Ultrafiltration membrane for solid-liquid separation with 1.5 – 2.0 bar of operational pressure. The wastewater has been extensively analyzed for six parameters which are pH value, biochemical oxygen demand (BOD), chemical oxygen demand (COD), volatile fatty acids (VFA), total suspended solid (TSS) and volatile suspended solid (VSS). The reactor is operated at ambient temperature and wrapped with aluminum foil to avoid direct sunlight, which can affect the bacteria. The raw sewage sludge was obtained from Indah Water Air Putih, Kuantan. Sewage sludge is tested using jar test for the chemical requirements to remove small particles in the waste water. The digester operates 5 hours every 4 days for 12 days. The product that been produce contained carbon dioxide and methane gas. Both gases are collected into a syringe that connected with two rubber tube and a glass tube. Compare to aerobic digestion which is expensive method since it used oxygen and anaerobic digestion that requires larger area and slower process, UMAS was being innovated and offer great advantages. Carbon dioxide is removed by manipulated the syringe using 10 ml of sodium hydroxide. Methane gas is measured once every four days. This treatment showed the best solution to treat waste water such as reduction of COD contents and increased percentage of methane gas. Thus, make UMAS is a good alternative for treating wastewater.

PENGHASILAN GAS METANA OLEH SISTEM MEMBRAN ANAEROBIK BERULTRASONIK MENGGUNAKAN SISA KUMBAHAN SEBAGAI SUBSTRAT

ABSTRAK

Satu kajian telah dijalankan untuk membuktikan keberkesanan Sistem Membrane Ultrasonik anaerobik (UMAS) dalam rawatan air sisa, kecekapan UMAS dalam pengeluaran gas metana dan parameter kinetik dalam sisa kumbahan kepada pengeluaran metana daripada sisa kumbahan dengan menggunakan (UMAS). UMAS terdiri daripada membran ultrasonik untuk pemisahan pepejal-cecair dengan 1.5 - 2.0 bar tekanan operasi. Air kumbahan telah dianalisis selama enam parameter iaitu nilai pH, Permintaan Oksigen Biokimia (BOD), Permintaan Oksigen Kimia (COD), Asid Lemak Meruap (VFA), Jumlah Pepejal Terampai (TSS) dan Tidak Menentu Pepejal Terampai (VSS). Reaktor dikendalikan pada suhu ambien dan dibalut dengan kertas aluminium untuk mengelakkan cahaya matahari, yang boleh menjejaskan bakteria. Sisa kumbahan telah diperolehi dari Indah Water Air Putih, Kuantan. Air kumbahan ini diuji menggunakan Ujian Balang untuk keperluan kimia untuk mengeluarkan zarah kecil dalam air sisa. Reaktor ini beroperasi 5 jam setiap 4 hari selama 12 hari. Produk yang telah menghasilkan yang mengandungi karbon dioksida dan gas metana. Kedua-dua gas dikumpulkan ke dalam picagari yang disambung dengan dua tiub getah dan tiub kaca. Ber bandingkan dengan pencernaan aerobik yang kaedahnya yang mahal kerana ia menggunakan oksigen dan pencernaan anaerobik yang memerlukan kawasan yang lebih besar dan proses yang perlahan, UMAS telah diubahsuai dan menawarkan lebih banyak kelebihan. Karbon dioksida dikeluarkan oleh dimanipulasi picagari menggunakan 10 ml natrium hidroksida. Gas metana diukur setiap empat hari sekali. Rawatan ini menunjukkan penyelesaian terbaik untuk merawat air sisa seperti pengurangan kandungan COD dan meningkatkan peratusan gas metana. Oleh itu, membuat UMAS adalah alternatif yang baik untuk mengolah air sisa.

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LIST OF SYMBOLS

%	Percentage
°C	Degree Celsius
°F	Degree Fahrenheit
Mg/L	Milligram/Liter
Mg/dm^3	Milligram/cubicdecimetre
L	Liter
M^2	Meter Square
G	Gram
µm	Micrometer
kHz	Kilohertz
ppm	Parts per Million
mL	Milliliter

LIST OF ABBREVIATIONS

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
UMAS	Ultrasonic Membrane Anaerobic System
VFA	Volatile Fatty Acids
TSS	Total Suspended Solid
VSS	Volatile Suspended Solid
H_2S	Hydrogen sulphide
NH3	Ammonia
N2	Nitrogen
CO_2	Carbon Dioxide
CH_4	Methane
HRT	Hydraulic Retention Time
OLR	Organic Loading Rate
UF	Ultrafiltration
UASB	Upflow Anaerobic Sludge Blanket
EFB	Empty Fruit Bunch
FFB	Fresh Fruit Bunches
POME	Palm Oil Mill Effluent
TVFA	Total Volatile Fatty Acid
MSW	Municipal Solid Waste
AD	Anaerobic Digestion
OF	Organic Fraction
VS	Volatile Solids
TS	Total Solids
MS	Medium Solid
HS	High Solid
RVS	Refractory Volatile Solids
BVS	Biodegradable Volatile Solids
DO	Dissolved Oxygen
RO	Reverse Osmosis
EDR	Electro Dialysis Reversal
MF	Microfiltration

CUF	Cross Flow Ultra-Filtration Membrane
NTU	Nephelometric Turbidity Units

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter will give the ideas about the significant of the research formulation. This first chapter will cover up the subtopic of background of research or information, problem statement, research objectives, research questions, scope of proposed research, and significance of the proposed research.

1.2 Research Background

Production of sewage sludge that increased lately have become an environment problem for engineers this field all over the world to dispose it into local rivers or lakes. The major organic loading originates from human excreta and is a complex mixture of fats, proteins, carbohydrates, lignin amino acids, sugars, celluloses, humic material and fatty acids. Primary sludge, material that settles out during primary treatment, often has a strong odor and requires treatment prior to disposal. Secondary sludge is the extra microorganisms from the biological treatment processes. The pH values were generally neutral which in range from 6.00 to 7.85. The Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) values were many higher before treatment process than after. The COD values of untreated sewage sludge amounted from 202 to 618 mg/dm^3, whereas BOD values are from 10000 to 20000 mg/L, 50 times more polluting than raw domestic sewage. On the other hand, high contents of organic matter and nutrients make sewage sludge a perfect material for fertilization and re-cultivation of degraded soils. The goals of sludge treatment are to stabilize the sludge and reduce odors, remove some of the water and reduce volume, decompose some of the organic matter and reduce volume, kill disease causing organisms and disinfect the sludge.

Anaerobic treatment which recently used is an economical option for municipal solid waste. Anaerobic is one of composting process; used to neutralize sewage sludge. The physical and chemical properties of sewage sludge are needed in designing and performance of anaerobic digestion which will affect the production of biogas. The benefits of anaerobic digestion are odor control and producing the biogas as a by-product. In the other hand, anaerobic processes require large area and have long retention time.

Membrane are used for separating two phases prevents the transportation of various chemicals in a selective manner. In membrane separation technology, feed stream into effluent streams called permeate and concentrate. The stream that is rejected by the membrane is called concentrate while the liquid that passes through the semi-permeable membrane is called as permeate. Ultrasonic produces wave that could prevent fouling in the process. Fouling is the accumulation of unwanted material on the solid surfaces that affect the function. Using Ultrasonic Membrane Anaerobic System (UMAS), the kinetic parameters that been observed are pH value, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Volatile Fatty Acids (VFA), Total Suspended Solid (TSS) and Volatile Suspended Solid (VSS). As the production of methane, a lean water which satisfies standards that been enforced in Environment Quality Act 1974 either standard A or B. Clean water that satisfied the standard can be disposed into local river or lakes.

1.3 Problem Statement

Through anaerobic decomposition of organic matter, it produces combustible gas which is methane and carbon dioxide with a little bit amounts of hydrogen sulphide (H_2S), ammonia (NH_3) and nitrogen (N_2). The biogas produce is one of alternative energy sources.

Membrane separations that been used widely nowadays gas separations for gas purification. Removal carbon dioxide (CO_2) from methane gas (CH_4) is one of the applications of gas separation. A further process through membrane filtration can produce clean water.

Since wastewater can be treated to become some sort of energy such as methane, it also produces carbon dioxide which leads to greenhouse gases. As one of the scope that we want to achieve through this research, that is we want to obtain high purity of CH_4 gas, CO_2 must be remove by using the suitable membranes.

1.4 Research Objective(s)

1.4.1 To evaluate the application of Ultrasonic Membrane Anaerobic System (UMAS) in wastewater treatment

1.4.2 To determine the kinetic parameters in sewage sludge

1.4.3 To examine the efficiency of Ultrasonic Membrane Anaerobic System (UMAS) in methane production

1.5 Scope of Research

In order to prove that ultrasonic membrane anaerobic system is the best way on treating sewage sludge as substrate, the scope of research is more focusing on:

1.5.1 To design 200 L of Ultrasonic Membrane Anaerobic System (UMAS)

1.5.2 To study the effect of hydraulic retention time (HRT) on performance of UMAS

1.5.3 To study the effect of organic loading rate (OLR)

1.5.4 To study the kinetic parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Volatile Suspended Solids (VSS), Volatile Fatty Acids (VFA) and pH

1.6 Research Question

What are significance when using open pond and closed pond (UMAS reactor) of anaerobic system?

1.7 Significance of Research

Sewage sludge is an end-product of biological wastewater treatment processes which contains pollutants such as heavy metals, organic pollutants and pathogens. This characteristic makes the sewage sludge being treated before disposal or recycling in order to reduce its content. From a waste to alternative energy sources, sewage sludge can be treated using anaerobic digestion to produce biogas which is methane and carbon dioxide. Since carbon dioxide leads to environmental problem: greenhouse effect, the removal of carbon dioxide done by using membrane.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

There are two main ways to treat raw sewage sludge. First with aerobic process and second is anaerobic process. Aerobic waste water treatment is a process where bacteria utilize oxygen to degrade organic matter (generally quantified as biochemical oxygen demand or BOD) to carbon dioxide and other pollutants involved in various production systems. The degradation of BOD is achieved through aerobic bacteria in a system. In contrast, this process quite costly which requires large number of oxygen been used to treat waste water. Thus, environmental engineers start to search and identify treatment that may benefits towards environment and human beings.

Anaerobic digestion is the natural breakdown of organic materials into methane and carbon dioxide gas. High rate anaerobic treatment of industrial wastewaters is a proven technology that offers many advantages such as high organic matter removal efficiency, recovery of energy, and excess sludge reduction (Recep, 2012). This takes place in Ultrasonic Membrane Anaerobic System (UMAS) reactor in which bacteria act without oxygen. Biogas is the name given to the mixture of gases formed during the anaerobic digestion of organic wastes (Monnet, 2003). Biogas consists of methane (70%) and carbon dioxide (30%). In this research, the main objective is to evaluate the application of ultrasonic membrane anaerobic system in wastewater (UMAS) treatment, determine the kinetic parameters in sewage sludge and to examine the efficiency of ultrasonic membrane anaerobic system (UMAS) in methane production. The methods of this study which includes the effect of hydraulic retention time (HRT) on performance of UMAS, effect of organic loading rate (OLR) and kinetic parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Volatile Suspended Solids (VSS), Volatile Fatty Acids (VFA) and pH.

Anaerobic treatment solve problems in costing for oxygen supply but still give some obstacles in collecting the biogas that need to be separated from the effluent. This could results in low purity of biogas that been produced. Thus, membrane is used to separate the biogas from the effluent.

The membrane used is Ultrafiltration (UF) membrane. Ultrafiltration (UF) is a separation process using membranes with pore sizes in the range of 0.1 to 0.001 micron. Typically, UF membranes will remove high molecular-weight substances, colloidal materials, and organic and inorganic polymeric molecules. Low molecular-weight organics such as sodium, calcium, magnesium chloride, and sulfate are not removed by UF membranes. Because only high-molecular weight species are removed, the osmotic pressure differential across the UF membrane surface is negligible. Low applied pressures are therefore sufficient to achieve high flux rates from an Ultrafiltration membrane.

Fouling is one of the most restricting problems that occur in membrane processes. Fouling is deposition of solids on the membrane which is irreversible affected by operation parameters during processing. One of newest of fouling reduction is application of ultrasonic waves at which the high-velocity fluid movement associated with the ultrasonically generated microstreamers, microstreaming, microjets and acoustic streaming.

2.2 Definition of Sewage Sludge

Sludge is a residual in semi-solid material. Sewage is a mixture of water from the treatment process (wastewater) from domestic and industrial life. Sewage sludge is also known as bio solids. Sewage sludge is a mixture of solid materials in a slurry form, product from the treatment process of settling of solids and partial biological decomposition. Sewage sludge is formed from wastewater; a combination of municipal liquid-carried wastes discharged from residential, institutional, commercial and industrial activities. It may consist of undesirable components, including organic, inorganic, heavy metals and toxic substances, as well as pathogenic (Oleszczuk, 2007). The organic solids contain a portion of proteins, carbohydrates, fats and oils in wastewater.

2.3 Importance of Processing Sewage Sludge

The average production of sewage sludge being estimated around 40 – 60 g dry matter per inhabitant per day for urban sewage plants which leads to two pressing problem; the environmental crisis and the energy shortage. As it is expected to rise, an adequate management of sewage sludge is fundamental need (Ghazy, 2009). There are four main reasons wastewater cannot be disposed in untreated form. Firstly, biological decomposition of the organic materials in wastewater consumes oxygen and reduces the quantity available in the receiving waters for the aquatic. In addition, the decomposition release large amount of malodorous gases. Secondly, untreated wastewater contains pathogenic or disease causing micro-organisms that hazardous to human being (Kacprzak, 2005). Thirdly, toxic compounds such as heavy metals can be very dangerous to both plants and animals (Laturnus, 2007). Lastly, the presence of phosphates and nitrogen may cause irregular growth of aquatic animals. As an economical way, land application of sewage sludge become the most effective dispersive method that been widely used around the world. The organic compound such as nitrogen makes the wastewater suitable to be used as fertilizers. This would overcome the environmental crisis (Erbardt, 2001). Although there are these several ways, it is better to make use of these waste materials by turning them into a resource. Methane is become one of the energy sources that could be produced by wastewater by several processes.

2.4 Anaerobic Processes in Waste Treatment

Anaerobic digestion is one of biological processes of stabilization or disinfection of treatment. The stabilization aims at reducing the fermentation of the matter contained in waste and the emission of odors whereas disinfection for removing pathogens. The main objectives of this process are reducing the odor generation and reduce the pathogen content of the waste (Okuda, n.d.). In the other hand, anaerobic digestion as purposed reducing, stabilizing and partially disinfecting the treated volume of waste. Anaerobic digestion is a natural process which biodegradable waste will eventually go through in the absence of air at most active in two temperature ranges, 95 to 105 °F and 130 to 135 °F. It involves microorganisms breaking down the waste and producing combustible gas; methane gas and carbon dioxide as by product. It also called biogas and an alternative energy sources. Biogas needs to be scrubbed if it is for generating electricity. Anaerobic digestion is suitable for treatment of agriculture wastes, household waste, garden and park waste, sewage sludge and solid waste products from food that will produce beneficial end-products. In UK, anaerobic digestion has been limited to small on-farm digesters recently. In the other hand, Europe country have widely used while in Denmark, has a number of farm co-operative anaerobic plants which produce electricity and district heating for local villagers, biogas plant have been built in Sweden to produce vehicle fuel for fleets of town buses. In Germany and Austria, several thousand on-farm digesters have been built to treat mixtures of manures, energy corps and food waste as production of biogas to generate electricity. An anaerobic digester or sealed airless container is a device which accelerates the digestion process and so the production of biogas. The properties of the digester itself create the ideal conditions for the bacteria or microorganisms to ferment the organic material (“Anaerobic Digestion”, 2007). It is fed with biodegradable waste, heated to the appropriate temperature and left to do its work. This process usually takes a couple weeks to a couple of months after which the residuals slurry can be removed, either continuous or batch-wise. Several options are available, ranging from simple digestion techniques to technologically complex designs on a household or municipal scale. Municipal scale is a large scale from a number of sources. A domestic anaerobic digestion technique `fixed dome type' consists of a simple biogas tank with a flat bottom and a round chamber covered with a dome shaped concrete gasholder. The gas is captured in the upper part of the digester. Gas pressure increases with the volume of gas stored, pushing the slurry into a separate outlet tank.

2.5 Anaerobic Treatment

Anaerobic digestion is affected by biological activity which relatively slowly reproducing methanogenic bacteria. These bacteria must be given sufficient time to reproduce, so that they can replace cells lost with the effluent and adjust their population size to follow fluctuations in organic loading. Maintaining a sufficient retention time for solids ensuring the bacterial cells remain in optimal concentration within the digester. The bacteria population in the digester will be eliminated of the system if the rate of bacteria lost from the digester with the effluent slurry exceeds the growth rate of the bacteria. Anaerobic digestion affected by the specific characteristics of feed substance, operational parameters such as hydraulic retention time (HRT), solid retention time (SRT) and environmental factors such as pH, temperature, design of reactor and available organic materials. Hydraulic retention time can be easily manipulated because it is possible to feed sufficient substrate by reducing it and increasing organic waste load. Designing a properly sized digester to obtain the maximum biogas production per unit of digester volume is important in maintaining low capital construction costs. The digester should be sized to achieve desired performance goals in both winter and summer, and must be large enough to avoid the population of bacteria being eliminated. Design goals for the digester maximizing gas production with minimal capital investment and a minimum of operational attention. Moreover, digester must achieving pollution control and reduction of pathogens. The most important target of designing digester is the production of sellable digested and composted biomass for use as a soil conditioner or fertilizer (Malakahmad, n.d.).

There are four types of anaerobic reactor that have been developed as follows:

- Up-flow Anaerobic Sludge Blanket (UASB) type units in which no special media have to be used since the high density sludge granules themselves act as the 'media' and stay in suspension. This will form a sludge blanket in the reactor. The waste is passed upward through the blanket. Because of its density, a high concentration of biomass can be developed in the blanket. These are commonly preferred.

- Fluidized bed units filled with sand or plastic granules are used with recirculation under required pressure to keep the entire mass fluidized and the sludge distributed over the entire reactor volume. Since the sand particles are small, a very large biomass can be developed in a small volume of the reactor. In order to fluidize the bed, high recycle is required. Their power consumption is higher.

- Anaerobic filter is generated on media. The bed is fully submerged and can be operated either up flow or down flow. High recycle is needed for high strength waste.

- Anaerobic Contact or an anaerobic activated sludge where the sludge is recycled from a clarifier or separator to the reactor. A vacuum degasifier is required in order to separate the gas from gas-liquid-solid mixture and avoid floating sludge in the clarifier.

2.6 Types of Anaerobic Process

Methanogenic bacteria are more sensitive to changes in temperature than other organisms present in digesters. The temperature effect also depends significantly on the solids concentration of the fermentation. Research has shown when high concentrations of organic loading were used (over 10 %), the tolerance for changes of 5 – 10 °C is much higher, and bacterial activity returns quickly when the temperature is raised again. Gas production efficiency generally increases with temperature, roughly doubling for every 10˚C rise between 15 ˚C and 35 ˚C. There are two types of digestion process which is mesophilic and thermophilic digestion.